Effect of Body Mass Index on Patients With Multiligamentous Knee Injuries

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**Purpose:** Our goal was to evaluate the impact of body mass index (BMI) on complications and associated injuries in patients undergoing surgical treatment for multiligamentous knee injuries (MLKIs). **Methods:** Over a period of 10 years, 126 MLKIs (123 patients) were included in the study. The inclusion criteria were (1) injury to 2 or more knee ligaments, (2) multiligament repair and/or reconstruction performed by 1 of 3 sports medicine orthopaedic surgeons at our institution, and (3) minimum of 1 year of follow-up. A chart review was performed to collect demographic data, mechanism of injury, ligaments involved, complications, and associated neurovascular injuries. Lastly, patients were divided by BMI into non-obese (<30 kg/m²) and obese (≥30 kg/m²) groups. **Results:** Of the 126 MLKIs, 87 occurred in non-obese patients and 39 occurred in obese patients. Surgical complication rates for non-obese and obese patients were 8.05% and 15.4%, respectively (P = .21). Revisions were needed in 8.05% and 5.1% of patients in these groups, respectively (P = .72). Three wound complications were found in the obese group only. Vascular injuries were found in 2.3% and 7.7% of patients in the non-obese and obese groups, respectively (P = .17). The rates of nerve injuries were 11.49% and 20.51%, respectively (P = .18). Patients in the obese group were most likely to have an MLKI from low-energy mechanisms, disregarding sports-related injuries (51.28%, P = .02). Using a logistic model and BMI as a continuous variable, we found that a 1-unit increase in BMI increased the odds ratio of complications by 9.2%, with statistical significance (P = .0174). In addition, post hoc power analysis using previous literature showed that this study could produce satisfactory power. **Conclusions:** Our results indicate that (1) obese individuals are significantly more likely to have an MLKI caused by low-energy mechanisms and (2) complication rates increase by 9.2% for every 1-unit increase in BMI. **Level of Evidence:** Level III, retrospective comparative study.
body weight placed on the knee joint from shifting body mass.

Given the increasing prevalence of obesity, the risk of neurovascular injuries in MLKIs, and the difficult postoperative course in these patients, further investigation of MLKI as it relates to BMI is warranted. Our goal was to evaluate the impact of BMI on complications and associated injuries in patients undergoing surgical treatment for MLKIs. We hypothesized that postoperative complications, as well as neurovascular injuries, revisions, manipulations under anesthesia (MUAs), and lower mechanisms of injury, would occur more frequently in obese patients.

### Methods

After we obtained institutional review board approval, a chart review was performed to identify patients who underwent surgical treatment for multiligamentous injuries from June 2003 to May 2013 at a single institution, performed by 1 of 3 sports medicine orthopaedic surgeons. The inclusion criteria were (1) injury to 2 or more knee ligaments (anterior cruciate ligament, posterior cruciate ligament, medial collateral ligament, and/or posterior lateral corner injury); (2) multiligament repair and/or reconstruction; and (3) minimum of 1 year of clinical or telephone follow-up. Patients with mental disabilities and prisoners were excluded from the study.

Demographic data, mechanism of injury energy (subdivided into high-energy mechanism, low-energy mechanism, or non-motorized sport–related injury), number of ligaments injured, neurovascular injury, treatment, return to the operating room for MUA, and complications (failed grafts, need for revision surgery, wound infections, or other medical complications postoperatively such as deep venous thrombosis [DVT] or pulmonary embolism [PE]) were collected. We reviewed each patient’s chart for any other major orthopaedic injuries at the time of the multiligament injury, as well as any non-orthopaedic injuries or complications.

Patients were further classified by BMI into 2 groups: non-obese (<30 kg/m²) and obese (≥30 kg/m²). Incidences of the aforementioned data collected were determined for both BMI groups. Statistical analysis was performed by a statistician using the $\chi^2$ and Fisher exact test to calculate statistical significance. Data were analyzed using a logistic model and BMI as a continuous independent variable. A post hoc power analysis was performed using literature published by Werner et al.\textsuperscript{11} based on their peroneal and vascular injury data using an $\alpha$ equal to .05 and power equal to 0.8.

### Results

We found 126 MLKIs in 123 patients. Of the MLKIs, 87 occurred in non-obese patients and 39 in obese patients, with mean BMIs of 25.0 kg/m² and 36.67 kg/m², respectively. The mean BMI for all patients was 28.8 kg/m². The mean follow-up period was 882.8 days for the non-obese group and 629.69 days for the obese group, with a rate of follow-up of 37.9% and 41%, respectively. The mean age was 25.86 years in the non-obese group and 28.1 years in the obese group. The non-obese group contained 20 female (22.99%) and 67 male (77.01%) patients, whereas the obese group contained 10 female (25.64%) and 29 male (74.36%) patients.

The surgical complication rates for the non-obese and obese patients were 8.05% (7 of 87) and 15.4% (6 of 39), respectively ($P = .21$). Complications included failed grafts (2 total), need for revision surgery (9 total), wound infections (3 total), and 1 DVT/PE (BMI, 51 kg/m²). The MUA rates in the 2 groups were 13.79% (12 of 87) and 12.8% (5 of 39), respectively ($P = .88$). Revisions were needed in 8.05% (7 of 87) and 5.1 (2 of 39) of patients in the 2 groups, respectively ($P = .72$) (Table 1). All 3 wound complications were found in the obese group only.

Vascular injuries were found in 2.3% (2 of 87) and 7.7% (3 of 39) ($P = .17$) of patients in the non-obese and obese groups, respectively. The rates of nerve injuries were 11.49% (10 of 87) and 20.51% (8 of 39) ($P = .18$), respectively. Patients in the obese group were most likely to have an MLKI from low-energy mechanisms (51.28%; 95% CI, 36% to 67%) (Table 2).

### Table 1. Rates of Complications, MUA, Need For Revision/Failed Grafts, Vascular Injury, and Nerve Injury in Obese Group (BMI ≥30 kg/m²) and Non-Obese Group (BMI <30 kg/m²)

<table>
<thead>
<tr>
<th>BMI (kg/m²)</th>
<th>No. of Patients</th>
<th>Complication (%)</th>
<th>MUA (%)</th>
<th>Revisions/Failed Grafts (%)</th>
<th>Vascular Injury (%)</th>
<th>Nerve Injury (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;30</td>
<td>87</td>
<td>8.05</td>
<td>13.79</td>
<td>8.05</td>
<td>2.3</td>
<td>11.49</td>
</tr>
<tr>
<td>≥30</td>
<td>39</td>
<td>15.4</td>
<td>12.8</td>
<td>5.1</td>
<td>7.7</td>
<td>20.51</td>
</tr>
</tbody>
</table>

**NOTE.** The 95% CI is shown in parentheses.

### Table 2. BMI as It Relates to Mechanism of Injury (Subdivided Into High-Energy Mechanism, Low-Energy Mechanism, or Non-Motorized Sport–Related Injury)

<table>
<thead>
<tr>
<th>BMI (kg/m²)</th>
<th>Sports Injury (%)</th>
<th>Low Energy (%)</th>
<th>High Energy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;30</td>
<td>5.63 (25-45)</td>
<td>22.99 (14-32)</td>
<td>41.38 (31-52)</td>
</tr>
<tr>
<td>≥30</td>
<td>15.38 (4-26)</td>
<td>51.28 (36-67)</td>
<td>33.33 (19-48)</td>
</tr>
</tbody>
</table>

**NOTE.** The 95% CI is shown in parentheses. *Statistically significant ($P ≤ .05$).
whereas non-obese patients were more likely to be injured from a sports-related injury (35.63%; 95% CI, 25% to 45%) or a high-energy mechanism such as a motor vehicle accident (41.38%; 95% CI, 31% to 52%) (Fig 1). The $P$ values when comparing the non-obese and obese groups regarding sports injuries, low-energy injuries, and high-energy injuries were .02, .0016, and .39, respectively.

In addition, we investigated knee dislocation, defined as an MLKI that involved both cruciate ligaments as well as 1 or more collateral ligaments. The rates were 33.33% (29 of 87) (95% CI, 23% to 43%) and 51.28% (20 of 39) (95% CI, 36% to 67%) in the non-obese and obese patients, respectively. The rates of 2-ligament injuries were 67.82% (59 of 87) (95% CI, 58% to 78%) and 48.72 (19 of 39) (95% CI, 33% to 64%), respectively ($P = .04$). Meanwhile, the rates of 4-ligament injuries were 2.29% (2 of 87) (95% CI, 0% to 5%) and 5.13% (2 of 39) (95% CI, 0% to 12%) ($P = .58$) (Table 3 and Fig 2).

Performing additional statistical analysis, we created a logistic model between BMI and complications, with BMI as a continuous independent variable. Using odds ratio estimates and Wald CIs, we found that a 1-unit increase in BMI increased the odds ratio of complications by 9.2%, with statistical significance ($P = .0174$). The odds ratio was 1.092 with a 95% CI of 1.016 to 1.174.

Finally, we performed a power (sample size) analysis using literature published by Werner et al.11 based on either their peroneal nerve injury data or their vascular injury data. Using these data as our standard and setting $\alpha$ equal to .05 and power equal to 0.8, we determined that a size of 39 patients per group was needed to yield adequate power. Our study analyzed 39 obese patients and 87 non-obese patients; therefore our study could produce satisfactory power.

**Discussion**

Our retrospective review of surgically treated MLKI patients found that obese individuals were significantly more likely to have an MLKI caused by low-energy mechanisms and that, for every 1-unit increase in BMI, complication rates increased by 9.2%. In addition, we found that neurovascular injuries and postoperative complications tended to occur more frequently in obese patients; however, revisions or failed grafts and MUAs were less likely in obese patients.

Increased body mass of patients remains a risk factor for low-energy knee dislocations. In agreement with the current literature, our study also found that obese individuals were significantly more likely to have an MLKI caused by low-energy mechanisms versus high-energy or sports-related injuries ($P = .0016$) (Table 2 and Fig 2).6-9,11 High-velocity dislocations most often occur in motor vehicle accidents, falls from a height, or severe crush injuries.12-14 Low-velocity dislocations most often occur during events of routine daily

**Table 3. Percentage of Patients With 2-, 3-, and 4-Ligament Injuries in Obese Group (BMI $\geq 30$ kg/m$^2$) and Non-Obese Group (BMI $<30$ kg/m$^2$)**

<table>
<thead>
<tr>
<th></th>
<th>2 Ligaments (%)</th>
<th>3 Ligaments (%)</th>
<th>4 Ligaments (%)</th>
<th>Dislocation* (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI $&lt;30$ kg/m$^2$</td>
<td>67.82 (58-78)</td>
<td>29.89 (20-39)</td>
<td>2.29 (0-5)</td>
<td>33.33 (23-43)</td>
</tr>
<tr>
<td>BMI $\geq 30$ kg/m$^2$</td>
<td>48.72 (33-64)</td>
<td>46.15 (31-62)</td>
<td>5.13 (0-12)</td>
<td>51.28 (36-67)</td>
</tr>
</tbody>
</table>

*Dislocation was defined as involvement of both cruciate ligaments as well as 1 or more collateral ligaments.

**Note.** The 95% CI is shown in parentheses. Statistical significance was defined as $P \leq .05$. 
activities such as falls of less than 5 ft or from stepping in a hole or off a curb.\textsuperscript{15-17} Werner et al.\textsuperscript{11} found that the mean BMI was significantly higher in their ultralow-velocity (ULV) cohort (49.1 kg/m\(^2\) \(v\) 34.1 kg/m\(^2\)). An increasing number of reported cases may suggest that low-energy knee dislocations, though infrequent, may be becoming more common. It is well known that obesity is widespread in the adult population, and we are continuing to see the effect of this epidemic on the practice of orthopaedic surgeons.

Several case reports have described low-velocity or spontaneous knee dislocations in obese patients.\textsuperscript{4-9} Peltola et al.,\textsuperscript{18} in a retrospective study of knee dislocations, evaluated the prevalence and cause of knee dislocations in patients with normal or increased BMIs. Of 24 patients, 11 (45.8\%) had BMIs that were greater than 25 kg/m\(^2\), and 2 of those 11 patients had BMIs greater than 40 kg/m\(^2\). Of the 11 overweight patients, 9 had sustained a knee dislocation due to low-energy trauma, defined as a ground-level fall, whereas the other 2 patients had sustained a knee dislocation while participating in athletics. Of the remaining 13 patients with BMIs of 25 kg/m\(^2\) or less, only 1 had a knee dislocation that was due to a simple fall whereas the other 12 patients had a dislocation due to either athletics or a high-energy mechanism. Our study also found that MLKIs undergoing surgical treatment were more prevalent in overweight and obese patients, with 86 of the 126 total MLKIs (68.3\%) occurring in patients with a BMI greater than 25 kg/m\(^2\). In this study we simply wanted to show that, in concordance with other studies, MLKIs are more prevalent in patients with increased BMIs.

The current literature has shown that the risks of associated neurovascular injuries are also higher in patients with increased BMIs.\textsuperscript{3,11,16,20} Azar et al.\textsuperscript{19} concluded that neurovascular injuries occur frequently with knee dislocations in severely obese patients and that the likelihood of combined neurovascular injury tends to increase as BMI increases. Vascular injury is reported to occur in 25\% to 30\% of all knee dislocations.\textsuperscript{3,5,13-15,17,21-26} The overall popliteal artery injury rate was 32\% and 23\% among all patients in the 2 largest studies on knee dislocation.\textsuperscript{21,27} In a case series of ULV knee dislocations by Azar et al., patients with vascular injuries had a mean BMI of 54 kg/m\(^2\) (range, 47 to 60 kg/m\(^2\)). Moreover, Werner et al.\textsuperscript{11} found that peroneal nerve injuries tended to occur more commonly in their heavier ULV cohort (39.1\%) compared with all other patients with MLKIs (8.4\%), as well as vascular injuries (28.1\% \(v\) 4.7\%). The rates of vascular and nerve injuries in our patients also showed an increased incidence in obese patients; however, neither was significant. Vascular injuries were found in 2.3\% (2 of 87) and 7.7\% (3 of 39) of patients in the non-obese and obese groups (\(P = .17\)), and nerve injuries were found in 11.49\% (10 of 87) and 20.51\% (8 of 39), respectively (\(P = .18\)) (Table 1). The rates of vascular injury were lower in our study than in other studies. The reported frequency of neurologic injury with knee dislocation varies greatly in the literature, with reports of 9\% to 49\% (mean, 22\%).\textsuperscript{19} The rates of nerve injury in our patients were lower than the average rates in both the non-obese and obese groups (11.49\% and 20.51\%, respectively). Azar et al. found that patients with nerve injuries had a mean BMI of 47 kg/m\(^2\) (range, 42 to 67 kg/m\(^2\)) and those with both nerve and vascular injuries had a mean BMI of 60 kg/m\(^2\) (range, 51 to 68 kg/m\(^2\)). Peltola et al.\textsuperscript{18} reported no peroneal nerve injuries and only 2 vascular injuries in their 11 obese patients; however, the mean BMI of these 11 patients was only 33 kg/m\(^2\) (range, 27 to 42 kg/m\(^2\)) in contrast to the mean BMI of 58 kg/m\(^2\) in the 11 patients with nerve or vascular injuries in the study by Azar et al. Our study found that patients with vascular injuries had a mean BMI of 29.8 kg/m\(^2\) whereas those with nerve injuries had a mean BMI of 30.19 kg/m\(^2\) (overall mean BMI, 28.8 kg/m\(^2\)).

It has been previously suggested that obesity is a risk factor for complications after knee dislocation.\textsuperscript{4,10,11} Hagino et al.\textsuperscript{5} reviewed the cases of 7 obese individuals (BMI >35 kg/m\(^2\)) who all sustained a knee dislocation. Obesity-related complications included deep wound infections in 3 patients, diabetic ketoacidosis in 2, and cor pulmonale in 1. Hagino et al. concluded that morbid obesity led to not only operative challenges but also unusual postoperative complications. Werner et al.\textsuperscript{11} in their retrospective review of 215 patients with MLKIs, found a significantly higher overall complication rate among the heavier patients with ULV MLKIs (73.9\%) compared with the entire MLKI cohort (21.4\%). In addition, Werner et al. reported that the ULV MLKI cohort had a higher reoperation rate, wound infection rate, and DVT rate. Although we did not observe ketoacidosis or cor pulmonale, we did observe 3 wound complications in the obese group only and 1 DVT that led to a PE in a patient with a BMI of 51 kg/m\(^2\). Although the increasing rate of complications in the 2 BMI groups was not statistically significant (8.05\% in non-obese patients and 15.4\% in obese patients, \(P = .21\)), we were able to conclude, using a logistic model with BMI as a continuous variable, that a 1-unit increase in BMI increased the odds ratio (1.092; 95\% CI, 1.016 to 1.174) of complications by 9.2\% (\(P = .0174\)). It is important to note that the rate of 2-ligament injuries was significantly lower in non-obese patients whereas the rates of knee dislocations and 4-ligament injuries were higher (not statistically significant) in the obese patients (Table 3), which may be an explanation for the increased rate of complications in the obese group.
The rate of complications may be decreased with careful attention to detail.\textsuperscript{15} Bilateral lower-extremity ultrasound has been suggested because of the high risk of DVT and PE in obese patients. Provisional joint-spanning external fixation for several weeks also may be beneficial in certain cases. In addition, postoperative rehabilitation has been highly variable in MLKIs and should be closely evaluated on a case-by-case basis to avoid unnecessary complications.

**Limitations**

Our retrospective study has several limitations that very similarly echo those of previous studies.\textsuperscript{11} Our tertiary-care center has a large referral area with economically disadvantaged patients, making it difficult to obtain patient follow-up. Our study was also based on an operative database of patients, leading to the inability to draw conclusions about nonoperative treatment in MLKIs. In addition, the rarity of MLKIs and small cohort of patients decrease the power and increase the difficulty in finding statistical significance. However, our cohort is among the largest in the current literature. Furthermore, categorizing high energy and low energy can be very subjective, especially when taking sporting injuries into account. Therefore we decided to treat high-energy, low-energy, and sporting injuries as separate variables. This could make it difficult to compare our study with previous literature that separated mechanisms of injury into only high or low energy. Finally, postoperative rehabilitation factors such as weight-bearing status, range-of-motion limitations, and bracing were difficult to assess and categorize because of the diversity of injuries and patient factors and could lead to confounding variables that were not taken into account.

**Conclusions**

Our results indicate that obese individuals are significantly more likely to have an MLKI caused by low-energy mechanisms. In addition, using a logistic model with BMI as a continuous independent variable, we found that for every 1-unit increase in BMI, complication rates increased by 9.2%.

**References**


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